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STEAM Education and Technological Innovation: New Models of Creative Learning

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Abstract
STEAM education (Science, Technology, Engineering, Arts, Mathematics) is an innovative educational framework, which incorporates an interdisciplinary approach and creativity as central elements of the learning process. The purpose of this article is to explore the relationship between STEAM education and technological innovation, as well as to present new models of creative learning, emerging from the combination of these two fields. It examines how it contributes to the development and cultivation of modern skills, while at the same time highlighting the importance of technological innovation in shaping a modern, inclusive and innovative learning environment. In the age of technology, STEAM education, integrating digital applications, artificial intelligence, robotics, augmented and virtual reality, is particularly important for the preparation of young people and employees for the modern challenges of the ever-changing global environment.

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1. Introduction

The rapid technological development that has led to the digital transformation of the economy, society, but also of many other sectors, has accelerated changes in education, schools and in general in the way the learning process is approached (Bogdandy et al., 2020; Oliveira et al., 2022). Modern educational environments based on cutting-edge technologies, such as Artificial Intelligence, Virtual, Augmented and Mixed Reality, proved to be particularly effective, due to the utilization of teaching innovations, which offered children exciting experiences and challenges, with simulations of real conditions for experiential learning (Ahmed and Sutton, 2017).

In recent years, all countries have set the integration of Information and Communication Technologies (ICT) in educational practice as the first priority of their educational policy. On the other hand, the human resources of education, due to lack of familiarity (Hussin, 2018), but also the ability to design the lesson, based on ICT (McDonald, 2017; Rich et al., 2021), are particularly reluctant to integrate new technologies and consequently didactic innovations into their teaching. For this reason, it is necessary to use ICT and the STEAM method in teacher training, enriching their digital skills, through online programs and online courses, adapted to their needs (Vander ark et al., 2020), but also allowing teachers to be fully informed about both their subject and technological developments (Darling-Hammond et al., 2020).

1.1. STEAM training

STEAM education, based on interdisciplinary learning, enhances creative thinking, cultivates social skills, and contributes to the all-round cognitive, emotional, and psychomotor development of students (Wu et al., 2022). After all, art has been added to the older method (STEM) in recent years, in order to cultivate children's creativity and aesthetic perception (Spyropoulou and Kameas, 2024). The addition of Art was considered necessary to enhance critical, creative thinking, holistic learning, and students' ability to tackle complex problems more effectively (Bertrand and Namukasa, 2020; Huser and Wadsworth, 2020). The positive effects of the method are multiplied when interdisciplinarity is enhanced by digital applications, such as artificial intelligence, robotics, smart devices, coding, etc. (Marín et al., 2021), making it a powerful method for the inclusion of students with learning difficulties (Tomar and Garg, 2021; Holmes and Tuomi, 2022).

The flexibility and adaptability of the STEAM framework in the utilization of new ideas and technologies, enables it to evolve and offer innovative teaching practices (Soroko, 2021a; Soroko, 2021b). Through interdisciplinary learning and the activation of modern teaching methods, a new educational framework is formed, which is more adapted to the labor market, emphasizing on emerging scientific institutions, such as natural sciences, technology, engineering and mathematics, had already been felt with the spread of industry in all productive sectors.

The integration of STEAM education in teaching is one of the most important factors of sustainable development, where along with technical, digital skills, social skills are also cultivated, such as communication, collaboration, critical thinking, problem solving, etc. (Xanthoudaki, 2017). This is achieved because both brain areas, convergent and divergent thinking, are utilized during teaching. After all, activities that require cooperation and teamwork, the high involvement of the student to solve a problem, the fact that knowledge is linked to everyday life, serve this purpose.

In recent years, the STEAM method has been influenced by contemporary emerging theories and practices that emphasize the role of technology in interdisciplinary learning. The integration of Data Science, the Internet of Things, Virtual, Augmented and Mixed Reality

(AR, VBR, MR), as well as other emerging technologies, has provided new opportunities for experiential learning and reflects a more general shift towards interdisciplinary approaches that further blur the boundaries between different disciplines (Chen et al., 2020; Liston et al., 2022).

1.2 The role of artificial ıntelligence (AI)

The question of whether a machine can "think" was first posed in 1950 by Turing (Tartuk, 2023). Artificial intelligence, linked to computer science, can generate symbolic inferences or promote logical behaviors (Demir and Güraksın, 2022), while in education it can be used in the fields of science, technology, engineering, and perform cognitive tasks related to the human mind, such as learning and problem-solving (Tartuk, 2023).

In today's conditions, the research interest in the smooth relationship between Computational Thinking (humans) and machine learning (computers) remains alive (Dohn, Kafai et al., 2022). After all, there is an inextricable relationship between Computational Thinking and Artificial Intelligence. Machine learning (ML), for example, relies on algorithms relevant to decision-making as they arise through data analysis or the algorithm-based type of Natural Language Processing (NLP) that understands natural language and promotes human-machine communication (Bellini et al., 2022).

The applications of AI contribute substantially to the upgrading of the quality of education, through the promotion of technological and teaching innovations. For example, ChatGPT enables dialogue, provides answers to questions, can process natural language, translate, provide text summaries, and generate text of various formats and styles (Malekos, 2023). Chatbots respond in real-time, solve queries, guide and support. Gradescope, a digital assessment platform, which has various grading tools that teachers can use, to grade faster, to give clear feedback to students, and to be informed about the degree of understanding of the concepts to be taught (Holmes and Tuomi, 2022; Hardman, 2023).

Also, the creation of simulations through AI applications provide an adaptive and active learning experience. In this way, students are given the opportunity to set hypotheses, experience their results and find out if the intended goals have been achieved. The simulation utilizes virtual, augmented and mixed reality or is a computer-based simulation or belongs to the serious games (Chih-Pu and Fengfeng, 2022).

Enhancing STEAM education with the help of artificial intelligence is one of the realities of our time. For example, the use of the Digital Personal Image Classifier (PIC) tool for image recognition, modeling, and application helps students learn basic engineering concepts. Thus, with the help of AI, children recognize images, with the experiment they understand Physics, create programs, apply electromechanical reactions and follow specific steps in solving problems (Hsu et al., 2021). According to the above, Artificial Intelligence includes and utilizes a wide range of technologies and approaches, such as machine learning, natural language processing (NLP), the use of computers and robotics (Dwivedi et al., 2021).

1.3. Robotics

Robotics combines AI with mechanical engineering to create machines that can perform human tasks and in doing so has the potential to change many areas of human activity, such as industry, agriculture, healthcare, and even the possibility of space exploration (Ertel, 2017). For example, large and small robotic arms enhance industrial production, while robots are leveraged from housekeeping services, to educational robots used to teach students STEM (Science, Technology, Engineering, and Mathematics) concepts, help them develop problem-solving skills, and encourage them to explore the world around them. Finally, robots can be

used as virtual assistants in the classroom, providing support to children and teachers (Shao et al., 2021; Grzybows ki et al., 2024).

Educational robotics (EP) is an interdisciplinary activity that mainly concerns the sciences of mathematics, information technology and technology (STEM, Science, Technology, Engineering and Mathematics) contributing significantly to the educational process. It is an environment constructed by computers, electronic components and electromechanical programs that work together and aim to explore different areas of knowledge. Instructional robotics is an effective and flexible teaching of learning that encourages learners (pupils, students, adults) to build and control machines using specific programming languages. In other words, it includes technical components and equipment that are programmed with various programming languages to execute various instructions. With the rapid evolution of robotics, robots have gone so far as to simulate human behavior, making people's lives easier and enhancing the advancement of science.

In education it allows students to experience new experiences, combine learning with fun and play, avoiding traditional teaching methods. It promotes a creative enjoyable way of learning while fostering collaboration, confidence, creativity, and resourcefulness. In addition, an important benefit of robotics is that it promotes innovation, developing the algorithmic and critical thinking of trainees, thus changing the learning process, adopting a different way of thinking, shaping opinions and options for their future involvement in various professions directly related to technology.

Educational robotics is not just a tool in the learning process but an entire field of science consisting of smaller scientific fields, while it can interact effectively with the STEAM method, improving the produced educational result. It aims to enhance the learning experience through the creation and implementation of activities where robots and technology play an active role, interacting with students and educators.

Although children's involvement in educational robotics can encourage their later engagement with computer science and STEAM sciences, robotics alone is not enough to lead to high learning outcomes. In order to achieve high learning results, it should work in combination with other sciences (STEAM), while at the same time teaching and learning should be enhanced through specially designed robotic platforms integrated into an appropriate educational framework that will have added learning value but also create an attractive learning environment for students. It is understood that educational robotics is a modern learning tool that offers a dynamic to the learning process and this is understood by the fact that an effort is made to integrate it into education from an early age. Its dynamics are also evident from the many corresponding competitions that exist regarding educational robotics.

The involvement of children with robotics from an early age can make the education of the subject of computer science more attractive and consequently enrich the motivation of students to deal with STEAM sciences either at an early age or even in later life. In contrast to traditional learning, the integration of robotics into the educational process has a different dynamic, broadens students' interest in the lesson, and makes the whole process more interesting for students, helping them develop their talents and their inclination to new technologies.

1.4. Immersive technologies and education

Immersive educational environments, based on cutting-edge technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) are particularly effective, due to the engaging experiences they offer, presenting students with interesting

challenges in realistic environments with simulations of real conditions, for experiential learning, increased engagement, and improved performance (Ahmed and Sutton, 2017). 3D digital applications form intensely interactive learning environments, which approach difficult and difficult concepts in a direct and experiential way.

Virtual reality (VR) is the product of interdisciplinary integration, which includes knowledge of optics, computer science, communication, microelectronics, mechanical engineering, and other disciplines. Virtual reality technology is widely used in many industries, especially in construction, entertainment, but also in other fields. Although it is already quite well-known and has been integrated into various disciplines, its application in education is still at an exploratory stage (Bai et al., 2020). VR is based on the principles of constructivist learning (Bani-Salameh et al., 2017). Exposing students to computer-simulated environments can make learning more effective (Chen et al., 2017), and this is because combining real and virtual environments would result in mixed reality, which would provide students with a wide variety of exploration options (Correia et al., 2016). Virtual reality devices have the ability to trick the senses so that the simulated world can be experienced as real.

Unlike virtual reality (VR), which fully immerses users in a simulated environment, augmented reality (AR) enhances the user's perception of existing reality. This is achieved by providing information that can take various forms, including visual elements (such as images, 3D models, and animations) and auditory elements (such as sounds and music). The key feature of AR is its ability to seamlessly blend the real and virtual worlds, creating a new, enhanced, and interactive experience. Examples of the use of AR such as: digital overlays in museum exhibits, interactive textbooks, and even its application in outdoor learning environments, show the breadth and adaptability of this technology. The rapid and continuous technological advancements highlight the importance of AR in education, and its utilization promises even more immersive and personalized learning experiences. The combination of AR with other educational technologies, such as virtual reality (VR), robotics, artificial intelligence (AI), but also its integration into the STEAM method in general, promises even more impressive learning results.

The term mixed reality (MR) refers to the technology that combines the physical and digital worlds, enabling the connection and interaction between real and virtual objects in real-time. This technology is a combination of the two aforementioned technologies, as it incorporates elements of Augmented Reality (AR) and Virtual Reality (VR), shaping a spectrum of experiences ranging from partially augmented environments to fully virtual spaces (MacCallum and Parsons, 2022). Its effective operation requires advanced sensory information interpretation techniques to create a coherent imaginary representation of the real and digital worlds. In this way, students act as creators of digital experiences, experiencing interactive experiences that contribute to a deeper understanding of complex concepts. At the same time, it offers the possibility of interdisciplinary learning and the development of digital skills, which are necessary for the production of innovative and original ideas and the preparation for the competitive modern labor market. (MacCallum, 2021).

In STEAM education, immersive simulations allow students to explore phenomena that are otherwise inaccessible or impractical, to be studied directly and in real environments. They also offer children the opportunity to design, analyze and implement virtual models using 3D modeling software and interactive environments, receiving immediate feedback on their designs without restrictions on physical materials and production processes. For example, these technologies can be used to visualize geometric shapes and relationships in three dimensions, making theoretical concepts more specific and intuitive (Sorby at al., 2016).

Interactive simulations can help students explore complex mathematical functions and graphical representations, leading to a better understanding of their fundamentals.

2. Material and Method

A systematic review of the literature was carried out, through PRISMA, while search engines for scientific articles, such as Google Scholar, Semantic Scholar, Scopus and ERIC (Education Resources Information Center), which are used extensively in academic research, serve different purposes and have a different way of operating, were used for data collection. In this way, key elements and results of research work were summarized and citation charts were used to explore the connections between documents, identifying the most influential references in their field and providing advanced filtering options. In order to achieve the greatest possible focus on the research topic, the literature research was divided into 4 main axes: STEM Education, Artificial Intelligence (A.I), Robotics and Immersive Technologies (AR, VR, MR).

The search for bibliographic sources was carried out in the two aforementioned search engines based on specific keywords. Initially, articles were searched on: STEAM Education and then the search included the terms: Artificial Intelligence, Robotics, Immersive Technologies as well as variations of these terms. Additional sources were sought based on terms such as: Interdisciplinary learning, Educational theories, Experiential learning, Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), Emerging educational technologies, always related to the STEAM education framework. Additional criteria for searching for scientific research and articles were the following: The files must be accessible, written in English, highly impactful, and have been published from 2000 to 2024. The studies selected met all the above criteria and presented the maximum relevance to the research question.

Although the methodology followed ensures a comprehensive, in-depth and comparative study, a number of limitations need to be recognised. The utilization of secondary data means that no primary empirical research, such as interviews or questionnaires, was conducted. Also, given the ever-evolving nature of technological developments, some recent developments regarding STEAM methodology, Artificial Intelligence, Robotics, and Immersive Technologies may not yet be fully reflected in the literature.

3. Results and Discussion

It is generally accepted that the integration of the STEAM method and new technologies in general into the learning process brings about significant changes, which contribute to fostering innovations in teaching and learning (Nwabueze and Isilebo, 2022). This is because, on the one hand, the interdisciplinarity and interdisciplinarity of the course is enhanced, and on the other hand, because the participation and interest of students is enhanced, as teaching becomes more experiential. At the same time, teachers teach based not only on the concept to be taught, but mainly on examples and experiences from children's daily lives (Kulkarni et al., 2022). After all, innovations in teaching are marked by the utilization of multifaceted teaching methods, adapted to modern educational requirements. The STEAM method is the alternative approach to teaching, where various areas of science are utilized with the aim of pluralism and the transformation of thought theory into practice (Burnard and Colucci-Gray, 2019).

STEAM is an interdisciplinary teaching method (Bertrand and Namukasa, 2020). At the same time, it is a tool that helps students solve real-life problems, offering creative solutions (Herro et al., 2019; Khikmiyah et al., 2021), while at the same time supporting the improvement of their technological skills, specifically through activities inside and outside of school, such as video production, digital drawings/sketches, visual tools, etc. At the same

time, it is a playful and fun way to learn the concepts to be taught (Wu et al., 2022), which is student-centered, relating concepts from different sciences, but also knowledge with technology. Children in an interdisciplinary way become familiar with technology, connect theory with practice, but also with their daily lives, acquire motivation for learning, plan, apply practices and solve problems, develop computational and synthetic thinking skills and understand the concepts of algorithms, programming and other scientific concepts, cultivate social skills and generally acquire skills that upgrade personal and professional growth.

The utilization of interdisciplinary teaching methods, using modern digital technologies, offers the possibility of personalizing learning experiences by adapting the educational content to meet the individual needs of each student (Dogan et al., 2023). At the same time, the integration of interactive elements, such as simulations or quizzes, supports learners' engagement and motivation (Aljarrah et al., 2021), while the use of AI-assisted algorithms by teachers helps to analyze student data, such as performance, preferences and learning pace, and to adapt educational content and activities to their individual needs (Baidoo-Anu and Ansah, 2023).

It is therefore understood that the future education of students must be adapted to the new requirements as they arise from modern reality. The strengthening of teaching innovation also requires modern teaching methods, adapted to the modern needs of the student, but also of education in general. STEAM education can provide the right educational framework so that learning is holistic, adaptive, interactive, and technologically enabled not just to keep up with developments, but to shape them.

4. Conclusion

The 4th industrial revolution is characterized by universal digitization and automation, but also by the widespread use of new technologies, creating new increased demands on both the training of human resources and the education system in general. The STEAM (Science, Technology, Engineering, Arts and Mathematics) educational framework is proposed as an alternative consideration to the teaching of cutting-edge subjects: Science, Technology, Engineering, Art and Mathematics. By supporting the transition to a more active learning approach, which promotes a deeper understanding of the theory and principles of these scientific fields, it emerges as a new, promising alternative model of education. The combination of STEAM technology with artificial intelligence, robotics and virtual, augmented and mixed reality, pushed aside traditional teaching and paved the way for modern pedagogical methods, which enhance student initiative, motivation and participation (Hu et al., 2020).

Despite the advantages of STEAM education in enhancing teaching and educational innovation, its integration into the educational context raises a variety of concerns regarding ensuring their effective, fair, equitable, and responsible use. Digital competence and the integration of STEAM in education also requires the appropriate knowledge, skills and attitudes. Unfortunately, although the majority of teachers try to find innovative learning processes, their knowledge of ICT skills and especially the STEAM method, is not always sufficient and there is a tendency not to use innovative processes in their lessons. On the other hand, the high cost of the method in financial and material resources, the risk of addiction to digital media and the lack of the necessary logistical infrastructure to support its application in the learning process, hardware malfunctions or software compatibility problems, are significant problems for its smooth and effective application in the learning process (Deterding et al., 2020; Salcedo et al., 2023).

Also, over-reliance on digital tools can lead children to be more interested in external rewards rather than inherent learning goals (Deterding et al., 2020), causing high competition,

increased and psychological pressure that can negatively impact the mental health and self-esteem of some students (Hamasha et al., 2024). Fostering a balanced pedagogical approach to the use of technology by educators can help alleviate these health concerns and ensure that students benefit from immersive learning experiences without adverse effects.

For the above reasons, the adequate training of the human resources of education is one of the factors for the successful integration of STEAM, but also of new technologies in general in educational practice. The continuous and up-to-date training of teachers will enhance their digital skills, strengthen their confidence in the use of digital tools in their teaching and generally improve the educational framework around the use of new technologies (Hamash et al., 2024).

In summary, for the smooth and effective integration of the STEAM method and by extension technological innovations in education, careful planning, correct and careful alignment with learning objectives, a specific implementation framework and sound pedagogical principles are required. Future research should focus more on exploring the long-term outcomes of the application of these technologies, both in terms of their positive effects on motivation, knowledge retention and skills improvement, and on the development of ethical guidelines and best practices, so that the use of immersive technologies in education helps to ensure their responsible and equitable application (Saputra et al., 2025).

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted. Authors can combine results and discussion if they wish.

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